Effect of Drying Methods on Raw Quality of Selected Cultivars of Arabica Coffee (*Coffea arabica L*.) Grown in South West, Ethiopia

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Abstract: ***Coffee Arabica is an essential commodity to the livelihood of millions of Ethiopians and its quality had critical importance to the coffee industry. A study was conducted to evaluate coffee quality attributes of nine newly released coffee cultivars subjected to open sun (direct sun light) and lath house-drying methods. The experiment was designed in complete randomized design factorial with two factors (cultivars and drying methods). Coffee cultivars were (Gawe, Dessu, 744, 7440, 74148, Gesha, Merdacheriko, Wushwush and Catimor J- 19) prepared using wet (washed) processing method during harvesting of 2017/18 cropping season, which were collected from different altitude of south west, Ethiopia. Raw quality was evaluated by a team of certified panelists at Jimma agricultural research center coffee processing and quality analysis laboratory. Cultivars of Dessu, 744 and Merdacheriko having best value in raw quality attributes, but, low values were recorded in Gesha cultivar. Drying method was no significant difference (P≥0.05) in raw quality parameters. Many of coffee cultivars showed significant differences (P≤0.05) on bean size screen in their scores. The interaction of cultivar and drying methods had resulted in significant difference (P≤ 0.05) on bean odor. In the future to improve and maintain coffee green bean quality different drying method should be practiced.***

Keywords: Coffee arabica, coffee quality, coffee cultivar, drying method

1. Introduction

The coffee bean is obtained from the fruit of the coffee plant, a small evergreen shrub belonging to the genus *Coffea*, family *Rubiaceae*. Although the genus *Coffea* is diverse and reported to comprise about 103 species (Davis *et al*., 2006), only two species namely Arabica (*Coffea arabica L*.) and Robusta (*Coffea canephora*) are under commercial cultivation (Lashermes *et al*., 1999; Anthony *et al*., 2002; Pearl *et al*., 2004). Arabica coffee accounts for about 70% of the world coffee production and known for the preparation of high quality beverage (Anthony *et al*., 2002). Ethiopia is the original home of *Coffea arabica L*, and thus, possesses the largest diversity in coffee genetic resources (Mayne *et al*., 2002; Girma, 2003). Coffee contributes the Lion's share in the national economy being the leading source of foreign exchange earnings (Taye *et al*., 2011). It is an essential commodity to the livelihood of millions of Ethiopians. The largest volume of coffee is grown in the two large regions of Oromia (in the central part of the country) and the Southern Nations, Nationalities and Peoples Region (SNNPR). Only five to eight percent of coffee production is grown on modern plantations, which are owned by private investors or by the government (Taye, 2013) Smallholder farmers grow the rest, and about half of that production is in backyards or gardens. In both cases (modern plantations as well as smallholder production), coffee is generally grown under shade (Beer *et al*., 1998).

Beverage quality often referred to as drinking quality or liquor quality is an important attribute of coffee (Muschler, 2001; Agwanda *et al*., 2003) and acts as yardstick for price determination (Walyaro, 1983). The term "green coffee bean" refers to un-roasted mature or immature coffee beans. These have been processed by wet or dry method for removing the outer pulp and mucilage, and have an intact wax layer on the outer surface. Coffee beverage quality is based on the characterization of a large number of factors including taste and aroma. A thousand of compounds, appearing during roasting are involved in coffee beverage quality. These compounds rise from a smaller number of biochemical compounds present in green beans. Walyaro (1983) recommended that beverage qualiy assessment as a sufficiently reliable for use as a basis of selection in quality improvement programs.

The criteria commonly used to evaluate the quality of coffee beans include bean size, color, shape, roast potential, processing method, storage period, flavor or cup quality, and the presence of defects (Franca *et al*., 2005).

Coffee drying is one of the most important steps in quality coffee production so coffee cherries are dried immediately after harvest to reduce moisture content in optimum level (10-11.5%), which allows safe storage over an extended period. Drying under open sun (direct sun light) using the solar radiations for food preservation are practiced since ancient times (Sharma *et al*., 2009). The use of direct sun drying process of coffee in terraces is still very common among the coffee producers (Correa *et al*., 2006). However, it requires high labor; it is a time requiring operation, dependent on the climatic conditions as well as leads to contamination by foreign materials. To overcome these s hort comings, various drying techniques have been proposed in recent time to maintain quality of products. Therefore, the objectives of this study were to evaluate both raw and cup quality of coffee as affected by differences cultivars and drying methods.

1.1 The objectives of the present study were:

To evaluate the effect of two drying methods (open sun and Net Lath house) on raw (physical) quality of the selected coffee cultivars grown in south west, Ethiopia.

1.2 Coffee Quality

The most important parameter in the appreciation of coffee quality is the organoleptic quality of the cup which is mainly due to the volatile substances present as well as sensory analysis referred to as cup quality. The cup quality is determined based on the level of mainly acidity, body and flavour of the brew (Yigzaw, 2006). Production and supply of coffee with excellent quality appear more crucial than ever before for coffee exporting countries. Quality coffee is a product that has desirable characteristics such as clean raw and roasted appearance, attractive aroma and good cup taste (Behailu *et al*., 2008).

ISO, (2000), defines cup coffee quality as the ability of a product to satisfy consumer's expectation by way of good sensory characteristics in the absence of off-flavors and different defects. The definition of coffee quality varies along the production-to-consumer chain (Leroy *et al*., 2006). At the farmer level, coffee quality is a combination of production level, price and easiness of culture; at the exporter or importer level, coffee quality is linked to bean size, lack of defects and regularity of provision, tonnage available, physical characteristics and price; at the roaster level, coffee quality depends on moisture content, stability of the characteristics, origin, price, biochemical compounds and organoleptic quality (Leroy *et al*., 2006). At the consumer level: coffee quality deals with price, taste and flavor, effects on health and alertness, geographical origin, environmental and sociological aspects (organic coffee, fair trade, etc (ISO, 2000).

The criteria for green coffee sale and purchase includes the geographic origin (country, region, state, plantation); the botanic origin (species, variety); the crop year; the moisture content; the total defect and foreign matter; the content of insect damaged beans; the bulk density and the bean size (ISO,9116). Coffee quality is conformance with requirements or fitness for use in which the parties involved in the industry (customer, processor, supplier, etc) should agree on the requirements and the requirements should be clear to all stake holders involved in the process (QSAE, 2000). On the other hand, Coffee quality control and auction center was established with a key objective of maintaining coffee quality control, which in turn facilitates the coffee marketing system to be standard based, and for the betterment /proper functioning of the long coffee supply chain of Ethiopia (Endale, 2008). Coffee quality inspection is universally applicable in both coffee producing and consuming countries according to the quality control system of the respective countries (CLU, 2007).

Coffee quality refers to beans flavor in fragrance, aroma, flavor, sweetness, acidity or overall taste felt by consumer after drink as well as physical characteristics such as length, width, thickness or weights, shape and color of coffee beans (Giomo *et al*., 2012).

Coffee has only one value to give the consumer pleasure and satisfaction through flavor, aroma and desirable physiological and psychological effects (Yigzaw, 2005). Therefore, coffee quality, especially liquor or cup quality, determines both the relative price and usefulness of a given quantity of coffee (Agwanda *et al*., 2003). Cup quality, often referred to as drinking quality or liquor quality, is an important attribute of coffee (Muschler, 2001; Agwanda *et al*., 2003) and acts as yardstick for price determination as cited by Anwar (2010).

1.3 Coffee bean drying

Drying is considered an important step in quality coffee production, since moisture levels higher than 12% can promote microbial growth and mycotoxin formation (Reh *et al*., 2006; Getachew *et al*., 2015). The main propose of drying is to maintain the moisture content of the parchment optimum for storage. Freshly pulped coffee has a moisture content of about 55% and that has to be reduced by drying to 11%. This is the ideal level of moisture content required for proper storage, hulling and roasting. In most of the developing countries, open sun drying is predominantly used and mainly by the producers' organizations/cooperatives, and the coffee is spread on the wire mesh tables for normally about two weeks in sunny days, until fully dry. Few commercial companies use mechanical drying method (Mutua, 2000). If drying is carried out too rapidly, 'case hardening' may occur which is common in the drying of many grains. The surface is over dried and shrinks irreversibly to prevent easy movement of moisture from within the bean in an outward direction. Field evidences have shown that when drying is done too rapidly under excessively warm temperatures, the valuable cup flavor is largely lost from coffee that otherwise would have been considered excellent (Sivetz and Foote, 2004). Lower *et al*., (2007) reported coffee beans may require more days to dry depending on the methods of drying and the density at which the beans are dried. (ICO, 2010) also confirmed that mesh tables characteristically wilt with the result that layer thickness, and consequently drying rates, are not uniform. For a given thickness layer, the length of the drying process depends mainly on weather conditions and degree of moisture content and size of the cherries (FAO, 2010). The digital method relied on a digital coffee moisture meter (tester), when correctly calibrated; it is the best method to determine moisture content of coffee rather than subjective method.

Poor drying operations, such as mixed drying and undesirable layer thickness of coffee upon drying and heaping of coffee before drying favor the development of fungus and bacteria that inevitably cause quality deterioration (Berhanu *et al*., 2014). For instance, the covering period during drying and depth of parchment or cherry layers affects the total time require to dry to an optimum moisture level, the extended drying time observed when drying depth and the duration of covering period increased (Bahailu and Solomon, 2006). Parchment coffee dried at the highest drying depth (5 cm) gave the lowest value of cup quality, while drying depth of 3 and 4 cm gave better values of cup quality (Bahailu *et al*., 2008). According to Beza (2011), drying was greatly affected by coffee types, processing and drying methods. Berhanu *et al*. (2014) reported that, coffee drying on raised beds covered with mesh wire or bamboo mat produced best quality coffee by scoring the highest raw and cup quality value of coffee bean. Similarly, Anwar (2010) reported that, coffees drying by using raised bed with mesh wire, wooden and bamboo mats have better quality. However, drying coffee directly on soil or dirty surfaces can lead to dirty or earthy flavors in the finished coffee (FAO, 2010). Also, coffee dried on bricks affect raw quality of the bean due less air movement that favor mold development and black (foxy) bean formation (Berhanu *et al*., 2014). Hence, inappropriate drying materials and place increase the black (foxy) bean formation that maximizes the degree of defect counts and affects the odor and color of the coffee that finally affects the raw quality of green beans. Drying together different day harvested cherries would affects the final quality of green coffee beans (Hicks, 2002; Selmar *et al*., 2006).

2. Materials and Methods

2.1 Description of Study Area

The study was conducted at Jimma Agricultural Research Center (JARC) and the coffee samples were obtained from Jimma (Melko), Tepi Agricultural Research Center and Gera sub center of JARC from harvests of 2017/2018 cropping season collected from coffee trees of 8 - 10 years age. Jimma Agricultural Research Center is located in Jimma zone, Oromia National Regional State, 358 km away southwest of the capital, Addis Ababa. The centre (Melko) is found at a distance of 10 km west of Jimma city and located at 7°40'37"N and 36°49'47"E and at an altitude of 1753 m above sea level. The average minimum and maximum temperatures are 11.9 and 26.2 °C, respectively. The area receives an average annual rainfall of 1532 mm (Lemi *et al.*, 2018). Teppi National Spice Research Center (TNSRC) is located in Yeki district, Sheka Zone of Southern Nations, Nationalities and Peoples' Regional State, which is 600 km away southwest of the capital, Addis Ababa. It is found at 35°08'28"E longitude and 7°08'54"N latitude and at an altitude of 1200 m above sea level.

The average minimum and maximum temperatures are 15 and 30 °C, respectively. It receives an average annual rainfall of 1630 mm (Shamil *et al*., 2017). The relative humidity of the site reaches 80 to 90% and the soil type is Nitosoil dominated by a loam texture (Girma *et al*., 2009). Gera agricultural research sub center of the Jimma agricultural research center is located at latitudinal gradient of 7°70"N and longitudinal gradient 36°35"E with an altitude of 1940 m above sea level. The mean annual rainfall of the area is 1878 mm with an average maximum and minimum air temperatures of 24.4 and 10.5 °C, respectively.

2.2. Experimental Materials and Description

Samples of nine coffees Arabica (*Coffea arabica L.*) cultivars adapted for mid land (1500-1750 meter above sea level), high land (above 1750) and low land (500-1500) altitudes were collected of the 2017/18 harvesting season at Jimma (Melko), Gera and Tepi growing areas. The coffee prepared samples were to represent each agro ecological zone. Harvesting was conducted in the period between mid of October and December 2017. Eight-kilo grams red ripe coffee cherries were harvested by hand picking from each selected coffee cultivars from the indicated areas and prepared by wet processing method.

2.3. Experimental Design

The experiment was arranged with two factors, coffee cultivars and coffee bean drying methods. The first factor consisted of levels with nine cultivars selected to represent d ifferent growing altitudes. The cultivars were Gesha, Catimo r J1, Dessu, and 744,7440,74148, Gawe, Merdacheriko and Wushwush. The second factor drying method consisted of two levels open sun drying and net lath house drying. Black net lath house transmits 48-50% UV light, measured by light meter (Extch, Model EA30, and Taiwan). From each coffee cultivar, samples were equally divided into each drying method and finally dried. Each treatment combination was done in triplicate and the experiment laid out in a Completely Randomized Design (CRD).

Table 1: Treatment combinations

S/N	Coffee cultivars	Drying methods	
		OS	LH
1	V_1	V_1O_S	V_1L_H
2	V_2	V_2O_S	$V_2 L_H$
3	V_3	V_3O_S	$V_3 L_H$
4	V_4	V_4O_S	$V_4 L_H$
5	V_5	V_5O_S	$V_5 L_H$
6	V_6	V_6O_S	$V_6 L_H$
7	V_7	V_7O_S	V_7L_H
8	V_8	V_8O_S	V_8L_H
9	V_9	V_9O_S	V_9L_H

OS = Open sun drying and LH= Lath house drying; V1= Gawe, V2= Dessu, V3=744, V4=74148, V5=7440 and V6= Gesha, V7=CJ-19, V8 = Wushwush, V9= Merdacheriko

2.4 Coffee Bean (Sample) Preparation

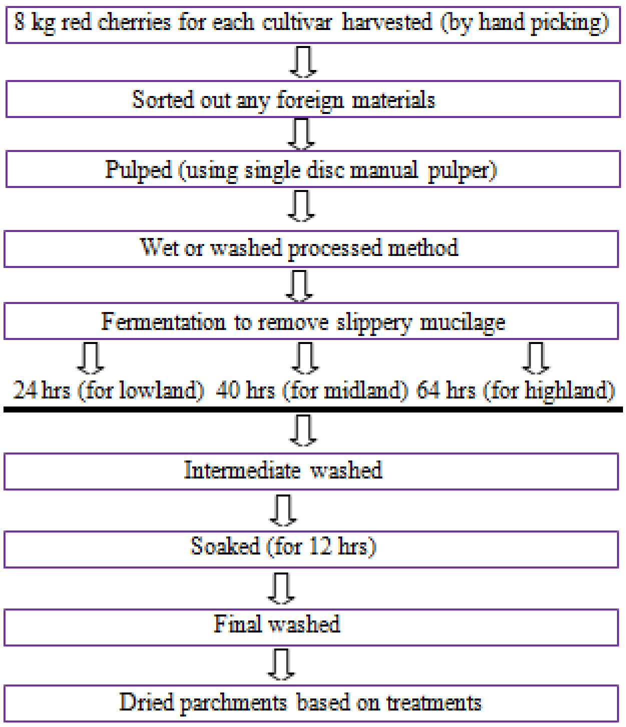

Figure 1: Sample (Coffee green bean) preparation

2.5 Data Collection

Green bean (raw) coffee quality evaluation: The green bean quality parameters were assessed as per standard of

Jimma Agricultural Research Center (JARC) coffee processing and quality analysis laboratory manual (Abrar S. and Nigussie M. 2015).The procedures applied to determine each quality parameter are described as follows:

Screen size of bean: It was conducted by means of rounded perforated plate called screen (Jos. Hansen and Soehne Hamburg). The screen size 14 is of whole diameter of 5.6 mm. Weight fractions of coffee bean retained above screen no.14 were recorded in percentage, which are defined in the international organization for standards (ISO, 1991).

Bean shape and make: It is the structural make up of different kinds of beans. Shape and make of coffee samples was evaluated by a team of cuppers out of score 15% only for washed coffee as very good (15), good (12), fair good (10), average (8), mixed (6) and small (4**)** and evaluated accordingly.

Color: It is the overall physical appearance of coffee beans and it was evaluated out of score 15% Only for washed coffee as bluish (15), grayish (12), greenish (10), coated (8), faded (6) and white (4) was evaluated accordingly.

Odor: It is the olfaction of coffee beans. It was evaluated out of score 10% for washed coffee as clean (10), fair clean (8), trace (6), light (4), moderate (2) and strong (0).

2.6 Statistical Data Analysis

Analysis of variance (ANOVA) was computed for each green bean and cup quality parameter data using General Linear Model (GLM) of SAS procedure version 9.0. In order to identify the variability among the treatments in CRD factorial design. For characters having significant mean differences, the difference between treatment means was compared using least significant difference (LSD) at 5% level of significance.

3. Results and Discussions

3.1. The effect of cultivars and drying methods on green bean coffee quality attributes

The green bean quality data of coffee as influenced by cultivars and drying methods are presented in Table 2. Screen size of bean was one of parameter affected by cultivars. Many of coffee cultivars showed significant differences (P≤0.05) on bean size screen in their scores. The values ranged from 96.03% (74148) to 98.75% of cultivar Gesha. Among cultivars having higher values such as Gesha (98.75%), Dessu (98.5%), 744 (98.5%) and Merdacheriko (98.5%) showed no significant difference (P≥0.05). Drying methods showed no significant difference (P≥0.05) on screen size of bean values of 97.78 and 97.48% scored by samples dried in lath house and open sun drying methods, respectively.

Many of the coffee cultivars exhibited significant (P≤0.05) differences in their scores for shape and make. Out of a maximum scale of 15 points, their scores varied between 11.42 of cultivar 74148 and 13.67 of cultivar Wushwush. Large number of them such as cultivars Dessu (13.50), 744 (13.33), 7440 (13.00), Wushwush (13.67) and Merdacheriko (13.50) were among the highest scorers with no significant (P≥0.05) difference. On the other hand, cultivars Gawe (12.00), 74148 (11.42) and Gesha (12.08) were of the lowest scores with no statistical difference (P≥0.05) among them.

Table 2: The effect of cultivar and drying methods on green bean coffee quality attributes

	Green bean coffee quality parameters			
Cultivars	Bean size screen	Shape and make	Color	Odor
Gawe	96.12[C]	12.00[d]	13.75[ab]	10.00[a]
Dessu	98.50[a]	13.5[ab]	14.08[a]	9.83[a]
744	98.50[a]	13.33[ab]	13.58[ab]	9.83[a]
74148	96.03[c]	11.42[d]	12.83[b]	9.66[ab]
7440	97.55[b]	13.00[ab]	13.50[ab]	10.00[a]
Gesha	98.75[a]	12.00[cd]	11.25[c]	9.33[b]
CJ-19	97.25[b]	12.83[bc]	13.92[a]	10.00[a]
Wushwush	97.45[b]	13.67[a]	13.67[ab]	10.00[a]
Merdacheriko	98.50[a]	13.50[ab]	13.42[ab]	10.00[a]
CV (%)	0.51	5.8	4.9	2.8
LSD (0.05)	0.66	0.8	0.9	0.4
Drying methods				
Lath house	97.78[a]	12.85[a]	13.44[a]	9.92[a]
Open sun	97.48[a]	12.78[a]	13.22[a]	9.77[a]
CV (%)	1.2	7.8	8.3	3.5
LSD (0.05)	0.6	0.55	0.6	0.2

Means having the same letter in columns are not significant difference (P≥ 0.05); CV = coefficient of variation, LSD = least significance difference.

Drying method showed no significant (P≥0.05) difference in regard to shape and make with values of 12.85 and 12.78 in scale 15 points scored by samples dried in lath house and open sun, respectively. Wintegens (2004) indicated that the shape and make of beans are the result of both genotype and environmental factors.

Color of green bean is one of raw quality parameter influenced by cultivars and drying methods. Some of the coffee cultivars exhibited significant (P≤0.05) differences in their scores for bean color. Out of a maximum scale of 15%, their scores varied between 11.25 of cultivar Gesha and 14.08 of cultivar Dessu. Most cultivars such as Dessu (14.08), CJ-19 (13.92), Gawe (13.75), Wushwush (13.67), 744 (13.58) and Merdacheriko (13.42) were among the highest scorers with no statistical difference (P≥0.05), while cultivar Gesha (11.25) and 74148 (12.83) were the lowest scores with no significant (P≥0.05) difference among them. Drying methods showed no significant (P≥0.05) difference on green bean color with values of 13.44 and 13.22 scored by samples dried in lath house and open drying method, respectively.

All concerned coffee cultivars except Gesha exhibited no significant (P>0.05) difference in their scores for bean odor. The effect of drying methods also caused no significant difference (P≥0.05) with value of 9.92 and 9.77 scored by samples dried in lath house and open sun drying method, respectively.

3.2. Interaction Effect of Cultivars and Drying Methods on Green Bean and Quality Attributes

Data of green bean coffee quality attributes such as color, screen bean size and odor of green bean influenced by interaction effect of cultivars and drying methods presented in Table 3.

One of the attribute is screen size that is the percentages of beans retained on the screen size number 14.The interaction of cultivars and drying methods had resulted in significant (P≤0.05) differences . The values ranged from 96.60 to 99.0% for combination of different cultivars and the two drying methods. The lowest percentage was recorded for cultivars Gawe and 74148 dried in both open sun and lath house. Whereas, the highest percentage happened to beans Dessu, Gesha and Merdacheriko cultivars dried in lath house. The data showed that all considered cultivars had beans with more than 96% retention on the screen size number 14. This implies that they are fit for international trade. According to Agwanda *et al*. (2003), bean physical characteristics such as bean size are unified criteria for conducting coffee business within the international market. However, it is not common to find harvests of beans of different screen size, which require size grading before marketing or processing.

The finding by Mekonen (2009) indicated that selective harvesting of coffee of different varieties showed significant variation in screen bean size. Open sun drying has resulted in more shrinkage resulting in the lowest percentage of 96.6% for cultivar Gawe and 98.5% for cultivar Gesha. This fact corroborates the reports of Coradi *et al*. (2007), who found that increasing temperature drying System causes damage to cell membranes coffee beans. The bold and medium bean size also has a particular importance to roasters, as uniform bean size would produce uniform roast (Yigzaw, 2005; EAFCA, 2008).

Analysis of variance for interaction of cultivar and drying methods showed that majority of the scores did not show significant (P≥0.05) difference in color score except Gesha that had the lowest score 9.83% (greenish) for beans dried in lath house. The majority of the sample had scores greater than 12% and less than 14% in scale of 15% showing that color wise they are more than good that is resembles to grayish color.

Coffee beans with the poorest appearance can be observed due to coffee type and processing methods (Sutherland, 1990). The best green blue coffee bean color can be obtained by removing the mucilage under fermentation after removing the pulp in wet processing (Anon, 2001).

The interaction of cultivar and drying methods had resulted in significant difference (P≤ 0.05) on bean odor. Out of a maximum scale of 10% points, the lowest value (9.00) was recorded for cultivar Gesha and similarly above this lowest value and below the highest score was recorded for 744, 74148 and CJ-19 cultivars dried by open sun drying method, while other considered cultivars had clean or unpleasant odor those were dried in both drying methods. The finding of Olamcam (2008) who explained that, properly harvested and processed beans are free of unpleasant (bad) odor.

Table 3: Interaction effect of drying method and cultivars of coffee on green bean coffee quality attributes

		Green bean coffee quality		
Cultivars	DM	Screen size of bean	Color	Odor
Gawe	LH	96.60^{ef}	13.67^{ab}	10.00^{a}
	OS	96.60^{g}	13.83^{ab}	10.00^{a}
Dessu	LH	99.00^{a}	14.17^{a}	10.00^{a}
	OS	98.00^{bc}	14.00^{a}	10.00^{a}
744	LH	98.5^{ab}	13.50^{ab}	9.67^{ab}
	OS	98.60^{ab}	13.67^{ab}	9.67^{ab}
74148	LH	96.00^{fg}	13.00^{ab}	10.00^{a}
	OS	96.00^{fg}	12.67^{b}	9.33^{bc}
7440	LH	97.10^{de}	13.33^{ab}	10.00^{a}
	OS	98.00^{bc}	13.67^{ab}	10.00^{a}
Gesha	LH	99.00^{a}	9.83^{c}	10.00^{a}
	OS	98.50^{ab}	12.67^{b}	9.00^{c}
CJ-19	LH	97.30^{cde}	14.00^{a}	10.00^{a}
	OS	97.20^{cde}	13.83^{ab}	9.67^{ab}
Wushwush	LH	97.50^{cd}	13.67^{ab}	10.00^{a}
	OS	97.40^{cde}	13.67^{ab}	10.00^{a}
Merdacheriko	LH	99.00^{a}	13.83^{ab}	10.00^{a}
	OS	98.00^{bc}	13.00^{ab}	10.00^{a}
CV (%)		0.51	4.94	2.76
LSD (0.05)		0.81	1.09	0.42

Means having the same letter in columns are not significant difference (P≥ 0.05) .DM= drying method; LH=lath house; OS =open sun; LSD= least significance difference; CV= coefficient of variation.

4. Summary, Conclusions and Recommendations

4.1. Summary

The effect of cultivar on green bean quality attributes such as, bean screen size, shape and make, color and odor were all significant (P ≤ 0.05). The bean screen size ranged from 96.03% of cultivar 74148 to 98.75% of cultivar Gesha. For shape and make, many of considered cultivars exhibited significant differences and the values ranged from 11.42 of cultivar 74148 to 13.67 of cultivar Wushwush. Drying method showed no significant (P≥ 0.05) difference on green bean quality attributes.

4.2. Conclusions

The effects of cultivars were not significant (P≥0.05) on odor except for cultivar Gesha. Cultivars of Dessu, 744 and Merdacheriko had best value in green bean quality attributes unlike the Gesha cultivar recorded with low values.
Drying method caused no significant difference (P≥0.05) in green (raw) bean quality parameters.

4.3. Recommendations

- Further studies should be under taken in the area of coffee bean drying methods to maintain and improve the quality of the bean obtained after harvesting including major chemical composition of beans.
- To avoid cracking and physical damage to the beans by overheating other drying method like net lath house drying is recommended rather than direct open sun drying. It is also important to prevent dust and dirt blown to drying parchments and to reduce labor cost.

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